blood, and gives a table of the invertebrates in which hæmocyanin and hæmoglobin have been found.—On the nature of papain and its action on vegetable proteid, by Dr. Sidney H. C. Martin. The proteids present in papain are globulin and albumin, and two forms of albumose. No peptones were found.—Regarding the influence of the organic constituents of the blood on the contractility of the ventricle, by Dr. Sydney Ringer (plate 9). He infers that the arrest of contractility with a saline solution is not due to the removal of pabulum to support the contractions, but that lime and potassium salts are necessary ingredients in a circulating fluid to supply the conditions essential to the change occurring during a contraction, there being stored up in the muscular tissue a material to carry on contractions which cannot be washed out by a fluid circulating in the heart cavities.—On the nature of glomerular activity in the kidney, by J. G. Adami. It would seem that the glomerular epithelium has properties of a definite secretory nature; they may even be regarded as (in the dog) having powers of a selective secretory nature.—Plethysmographic and vaso-motor experiments with frogs, by Dr. Fred. W. Ellis (plates 10 and 11).—On some vaso-motor functions of the spinal nerves in the frog, by W. Horscraft Waters.

The Journal of Anatomy and Physiology for January 1886, vol. xx. part 2, contains:—Prof. Macalister, morphology of the arterial system in man, part i.—R. Austin Freeman, the anatomy of the shoulder and upper arm of the mole (plate 5).—Dr. Hans Gadow, on the reproduction of the carapax in tortoises (plate 6). In the case experimented on, the dermal armour was cast off, after injury, down to the soft cutaneous layers; the bulk of these produced cutis, which then underwent the normal process of ossification, until at last a new complete armour was formed. The author cites, as an analogous case, "the reproduction of bark from the *whole surface of the cambium* laid open after the destruction of the old cortex." Is this so?—Dr. A. M'Aldowie, on the development and decay of the pigment-layer in birds' eggs.—Dr. D. J. Cunningham, the connection of the os odontoideum with the body of the axis.—Dr. R. W. Shufeldt, on the skeleton of Geococcyx (plates 7-9); a very full account of the skeleton of this rare bird.—Dr. Noël-Paton, relationship of urea-formation to bile-secretion; part ii. of these important experimental researches. The formation of urea in the liver bears a very direct relationship to the secretion of bile by that organ.—Dr. W. Hunter, recent histological methods.—Prof. W. Turner, the sacral index in various races of mankind; makes two classes—where the sacral index is below 100 (Dolichohieric), and where it is above 100 (Platyhieric).—Dr. J. L. Gibson, the blood-forming organs and blood-formation, part ii.

Zeitschrift für wissenschaftliche Zoologie, Band xliii. Heft 1 (Leipzig, December 31, 1885), contains:—Prof. A. Kölliker, histological studies of Batrachian larvæ (plates 1 and 2). Almost forty years ago Prof. Kölliker published his first account of the development of the Batrachian tissues, but the improvement in methods of research and the expansion of knowledge as to nerve-bundles and other endings have caused him to alter his opinions on several matters, and in this memoir we find his latest views on the structure, development, and terminations of the nerves; also some general considerations of the structure of the nerve-fibre and on the development of the blood- and lymph-vessels.—W. Schwarze, on the post-embryonal development in Trematodes (plate 3). These researches were made on *Cercaria armata* and *C. echinata* from *Limneus stagnalis*, and on *C. ornata* and *C. spinifera* from *Planorbis corneus*. A useful bibliography of the literature is appended.—Hermann Uhde, on the dorsal pore of the terrestrial Oligochæts: a contribution to the histology and classification of the Lumbricidæ (plate 4). In this memoir, in addition to a very detailed list of the literature of the subject and to a chapter on anatomical details, we have an account of the various species, based on materials collected from various parts of the world.—Dr. Deichler, on Protozoa parasitic in the sputa of whooping-cough.—Dr. E. Witlaczil, on the morphology and anatomy of the Coccidæ (plate 5).

Morphologisches Jahrbuch (*Gegenbaur's*), Band xi. Heft 3 (Leipzig, 1885), contains:—Dr. Béla Haller, researches on the marine Rhipidoglossa (plates 17-24), part ii. The first part of Haller's researches appeared in vol. ix. The present part treats of the structure of the central nervous systems and their envelopes. The material operated on was obtained at Trieste from Fissurella, Haliotis, and Turbo, and the conclusion is arrived at that without doubt the nerves throughout this group of Mollusca have a double origin.—Dr. H. Virchow, on the form of the plicæ of the ciliary body in mammals (plate 25). These folds, so comparatively small in the human eye, are largely developed in the rabbit.—Dr. W. Pfitzner, on the division of the nucleus in Protozoa (plate 26). These observations were chiefly on the nuclei in *Opalina ranarum*, and show the general similarity of the kariokinesis in this Protozoon with that in Metazoa.—Dr. G Baur, notes on the "astragalus" and the "intermedium tarsi" in mammals (plate 27). As introductory to these notes a very copious account of the literature of the subject is given.—Among the short notices are: on the nerve-canal in the humerus of the Amniota, by Prof. U. Fürbinger; and on the rudiment of a septal nasal gland in man, by Prof. Gegenbaur.

Rendiconti del Reale Istituto Lombardo, January 21.—On the grape-vine mildew; observations and remedies, by Prof. Gaetano Cantoni. Although usually supposed to have been for the first time introduced into Europe from America about 1877, the writer quotes a correspondent in the *Bulletin* of the French Agricultural Society, who states that this disease was known in Alsace under the name of *mildau* over forty years ago. From Alsace it passed to America, where the name became Anglicised, recently returning to Europe under the designation of grape-vine mildew. The best prophylactic remedies hitherto discovered are the sulphate of copper and milk of lime, applied either separately or in combination about the beginning of June, and repeated, if necessary, towards the end of August or beginning of September.—On the formation of dew, by Prof. Giovanni Cantoni. It is shown that the theory recently communicated by Prof. Aitken to the Edinburgh Royal Society and described in NATURE for Jan. 14 (p. 256), agrees with the conclusions already arrived at by Fusinieri, Melloni, and other Italian meteorologists.—Summary of the meteorological observations made at the Brera Observatory, Milan, during the year 1885, prepared by E. Pini.

Mittheilungen der Naturforschenden Gesellschaft in Bern, Nos. 1092-1132 (1884-85).—Wind and precipitates in Bern (from records of Bern Observatory during fifteen years), by Herr Benteli.—On a case of rapid hole-formation in rock, by Herr Baltzer.—On lake-balls, by Herr Coaz.—On the theory of trisection of angles, by Herr Moser.—On the termination of nerves in striped muscles of man, by Herr Flesck.—On a case of loess in Canton Bern, by Herr Baltzer.—On the oldest map of Switzerland of Ægidius Tschudi, by Herr Graf.—Mathematical researches on the colour of thin gypsum plates in polarised light, by M. Jonquière.—On the poisoning with *Amanita phalloides* in Bern in 1884, by Herr Studer, jun.—On the occurrence of the vascular wave in the carotid-curve, by Herr Mützenberg.—Contributions to a comparison of the brain-fissures in Carnivora and Primates, after examination of a lion's brain, by Herr Familiant.—On the chemistry of food-stuffs, by Herr Fueter-Schnell.—On a new occurrence of rock-crystal in Switzerland, by Herr von Fellenberg.

Verhandlungen der Schweizerischen Naturforschenden Gesellschaft in Lucerne, September 1884.—We note here the President's (Herr Suidter-Langenstein) opening address, dealing with the Lucerne region in geological, meteorological, and biological aspects; also two interesting reports on prize competitions—one relating to a climatology of Switzerland, the other to the deep-water fauna of Swiss lakes.

Journal de Physique, February.—On refrigerating mixtures and the principle of maximum work, by M. Potier.—On the critical temperatures and the pressures of some gases, by MM. Vincent and Chappuis.—Researches on the freezing temperature of solutions, by M. Raoult.—On the formula of plane gratings, by M. Branly.

SOCIETIES AND ACADEMIES

LONDON

Royal Society, December 10, 1885.—"On the Magnetisation of Steel, Cast Iron, and Soft Iron." By John W. Gemmell.

In this paper the author describes and gives the results of a series of experiments upon particular specimens of iron and of steel. The specimens consisted of wires of "soft Scotch iron," "common wire," "charcoal iron," and "soft steel," with bars of cast iron and malleable iron; and the object of the investigation was to find the difference between these, with respect to the intensities of their total and residual magnetisation, due to different degrees of magnetising force.

The apparatus was arranged, and the experiments made, according to a simple magnetometric method fully detailed in the paper. The magnetising currents were derived from a battery of Thomson's tray Daniells, so arranged that any number of cells could readily be placed in the circuit.

The results represent the effect of a current gradually increased from 0 to the maximum, gradually diminished to 0 again, and of the same process repeated with a negative current. They are shown in curves, the abscissæ of which are proportional to the magnetising forces, and the ordinates to the magnetisation produced. Figures are given by which to reduce these values to absolute measure.

It has been found that the "charcoal iron" has the highest magnetisability, and the "soft steel" the lowest; while that of the "soft Scotch iron" approaches the former. With regard to retentiveness, the "charcoal iron" shows the least, and the "soft steel" the greatest. Annealing the latter, however, has the effect of bringing it very near the "common wire," both in respect of magnetisability and retentiveness. The two specimens of cast iron differ considerably. The malleable iron bar shows a very much higher magnetisability than the cast iron ones, and its residual magnetisation was so low that it could not be observed with the same arrangement of apparatus.

These curves also present certain anomalies which are worth investigation. The space about the zero on an enlarged scale is affixed to each set to show its peculiarities more clearly.

In the curves representing the residual magnetisation we find a loop between the direct and return curves, more or less marked in all the diagrams. A similar feature presents itself in the curves of total magnetisation in two of the diagrams, and there seems to be a tendency always to form this loop.

In that part of the return curve which represents the effects of the small magnetising forces, the residual magnetism is seen first to take a greater value, and then to diminish again just before the zero of magnetising force is reached. This may be observed also in the negative return curve.

January 21.—"On Radiant Matter Spectroscopy: Note on the Spectra of Erbia." By William Crookes, F.R.S.

I have recently succeeded in getting the earth erbia in a sufficiently pure state to allow me to examine its phosphorescent spectrum without the interference which might be produced by the presence of yttria, samaria, holmia, thulia, Yα, or ytterbia. As in the case of yttria,[1] the spectrum is best seen when erbic sulphate is heated to redness and submitted to the electric discharge in a high vacuum. The addition of calcic sulphate interferes with the purity of the spectrum. In this respect erbia differs from samaria, as the latter earth seems to require the presence of some other metal to develop its phophorescent properties.

The phosphorescent spectrum of erbia consists of four green bands, of which the following measurements have been taken:—

Scale of spectroscope		λ		$\frac{1}{\lambda^2}$		Remarks
9°·750	...	5564	...	3230	...	Approximate centre of a wide band, shading off at each side.
9·650	...	5450	...	3367	...	Approximate centre of a band, narrower and somewhat fainter than the first band.
9·525	...	5318	...	3536	...	Approximate centre of a narrow band, bright and moderately sharp on each side.
9·400	...	5197	...	3702	...	Approximate centre of a band, similar in appearance to the first band, but brighter.

These bands do not correspond in position to any in either the yttrium or samarium spectrum. The nearest approach to a coincidence is between the first erbia green and the samarium green, but when the two spectra are examined one over the other it is seen that the samarium band is less refrangible than the erbium band.

The first green of Yα occurs midway between the first and second greens of erbia, and the second Yα green comes between the second and third erbia greens.

Pure erbia is of a beautiful rose-pink colour. When illuminated by sun or electric light and examined in the spectroscope it gives a spectrum of black lines and bands as sharp and distinct as the Fraunhofer lines. It is strange that this most characteristic property has been recorded by so few observers. Indeed, the only notice of it I have come across is a passing remark of Prof. Clève's that "the light reflected by dry erbia shows absorption bands."

The absorption spectrum given by a solution of pure erbic chloride differs in some respects from the drawings mapped from older observations, as the absorption lines of holmia and thulia are absent. The fine group of lines in the green of the reflection spectrum is also absent in the absorption spectrum.

The spectrum of bright lines emitted when erbia is rendered incandescent in the blow-pipe flame has been often observed, but the lines in this case are luminous on a fainter continuous background, and are not particularly sharp, whilst the reflection spectrum consists of black lines sharply defined on a continuous spectrum.

February 4.—"A Further Inquiry into a Special Colour-Relation between the Larva of *Smerinthus ocellatus* and its Food-plants." By Edward B. Poulton, M.A., of Jesus and Keble Colleges, Oxford. Communicated by Prof. J. S. Burdon-Sanderson, F.R.S.

The object of the paper was to give an account of the investigation upon this subject which had been undertaken in 1885, having been continued from the previous year (described in *Proc. Roy. Soc.*, No. 237, 1885, p. 269). The points which had been raised, and upon which evidence was desired, were as follows:—(1) The larvæ are generally uniformly coloured on the same food-plant, but sometimes there are exceptions; can any of these be due to the hereditary transmission of the influence of food-plants upon the parent larvæ? (2) Is the colour of the larva influenced by the colour of the environment which, acting upon some sensory surface, directs the kinds and amounts of pigments deposited, or absorbed from the food? (3) It was also important to test the effects of certain new food-plants and of others about which the evidence was conflicting; and (4) to look out for any indications which would throw light upon the red-spotted varieties, or upon the existence of individual variation of any kind, under similar conditions of parentage and food; and (5) to inquire into the periods during which the larvæ are most susceptible to the colour-influence.

Experiments in 1885.—These were divided into five series, as the larvæ came from five batches of eggs. The differences between the larvæ are expressed in five degrees: white, whitish-intermediate, intermediate, yellowish intermediate, and yellow. *Series I.* Eggs were laid by a moth bred from a larva which had been a typical whitish variety (as was also the case with the male parent). The resulting larvæ were whitish (5) upon *Pyrus Malus* (var. *acerba*), intermediate (1) upon *Populus tremula* and another species of poplar, intermediate (1) upon *Salix babylonica*, and whitish (2), although they did not become adult, upon *S. rubra* and other similar species of sallow. In this series the hereditary influence on the side of white is seen to be strongly marked on comparing the effects with those shown in the other series and in the parent larvæ (see former paper). *Series II.* Eggs were laid by a moth bred from a whitish-intermediate larva, without any act of coitus having been witnessed (although male moths were present). Most of the eggs shrivelled up, but a few hatched, and form the larvæ of this series. Subsequently coitus was induced (artificially), and a large number of fertile eggs were laid which are considered under the next series. The larvæ of Series II. were whitish (4) upon *Salix viminalis*, although not to such an extent as upon apple, and yellowish-intermediate (1) upon *S. Smithiana* and another sallow with similar leaves. These results are rather irregular, for the former larvæ were whiter than the parents, the latter yellower than it is probable that the parents would have been on the same tree. But the results were not unusual in themselves. *Series III.* The female parent was the same as in Series II.; the male parent was bred from a typical whitish larva. The resulting larvæ were whitish (6) upon ordinary apple, and upon the same with the leaves sewn to expose the under sides (1), and to expose the upper sides (3) (none of these reached maturity, and the last lot were especially young when they died); whitish (4) but immature upon crab (var. *acerba*); whitish-intermediate

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[1] *Phil. Trans.*, part iii., 1883, p. 913 (par. 71).

(5) upon *Salix viminalis;* white (1) but immature upon *S. viminalis*, sewn to show the under sides; yellowish-intermediate (2) but immature upon *S. alba;* whitish-intermediate (4) but mostly immature upon *S. Smithiana* and similar leaves; intermediate (1), yellowish-intermediate (5), and yellow with traces of the red spots (1) upon *S. cinerea;* intermediate (1) upon *Populus nigra;* intermediate (6) and yellowish-intermediate (2) upon *S. triandra;* yellowish-intermediate (10) upon *S. triandra* without the bloom on the under sides of the leaves; yellowish-intermediate (4) upon *S. babylonica* (when the larvæ were young and more numerous, one of them in the fourth stage possessed traces of the upper row of rust-coloured spots, and was a whitish variety: it was put upon apple and died as an intermediate variety when advanced in the last stage); intermediate (1) and yellowish-intermediate (3) upon *S. rubra.* The results of these experiments were mostly what might have been anticipated from the colour of the leaves. The especially interesting results were: the effects produced by the sewn leaves of *S. viminalis* and the bloomless leaves of *S. triandra* as compared with the normal leaves in both cases, and the occurrence of red spots on two larvæ—one, the only yellow variety obtained, and the other an intermediate variety. The indications of individual variation in the *S. cinerea* larvæ were also interesting. *Series IV.* All these larvæ died before trustworthy observations could be made; they had been reserved for experiment: the ocelli of many were covered with a harmless opaque layer (lamp-black and McGuilp) in the attempt to isolate the sensory surface which is affected by the colour of the environment. Others were fed upon apple and *S. rubra*, and a certain number were changed at every stage, so as to find the periods during which the larvæ are most susceptible to the surrounding colour. The failure of all these was due to the season and not the conditions of the experiment. *Series V.* The female parent was bred from a yellowish-intermediate larva, the male parent from a yellow larva. The resulting larvæ were, intermediate (1) upon *S. viminalis* sewn to show the upper sides of the leaves; intermediate (1) and yellowish-intermediate (1) upon *S. cinerea.* The first result was interesting, but the second shows that the larvæ did not tend much towards yellow. The hereditary influence towards yellow in this case depends chiefly on the male parent, and how far this element asserts itself in opposition to the other sex is quite unknown in this class of experiment.

Results of the Experiments.—The existence of hereditary influence is, on the whole, demonstrated. The parent larvæ tended towards white, and out of the 75 larvæ of the next generation, there was only one yellow variety. Yet the latter were, on the whole, rather more influenced in the direction of yellow than the parents, when the plants tended this way. The results were the same as in the parents when very powerful white influence was used (apple, &c.) The comparison of the different series was less satisfactory, but the hereditary differences were mostly delicate, except between V. and the other series.

Series I. and III. compare favourably, while in II. the parentage is very obscure. There is conclusive proof that it is the colour of the leaf, and not its substance when eaten which influences the larval colours.

Conflicting evidence as to the effect of plants is cleared up. *S. triandra* produces yellow; and Mr. Boscher's white larvæ, said to have been found upon this plant, occurred upon the very similar, but much whiter, *S. alba.* Previous conclusions as to *S. Smithiana* and *S. babylonica* are confirmed. The existence of individual variation with similarity of parentage and conditions is now proved, although it is rare and slight (8 out of 75 in 1885, 0 out of 23 in 1884). Thus it cannot explain the extreme differences met with in the field (1884), *e.g.* yellow upon apple, &c. The colours of the larvæ are determined by (1) the food-plant; (2) hereditary influence; (3) individual variation. Slight differences may be caused by the latter; extreme differences by the two former. The uncertain action of (1) will be shown later. The two red-spotted larvæ were very interesting, showing how the character tends to appear on the yellow varieties (the only yellow one produced), and yet that it may appear upon the other varieties (which is a new experience).

Observations in the Field in 1885.—(1) White variety upon ordinary apple; (2) white and (1) intermediate upon *S. viminalis;* (1) yellowish-intermediate upon *S. linearis* (Forbes); (1) yellow upon *S. incana* in Switzerland; (1) white upon *S. alba* (ordinary) in Switzerland; (1) yellowish-intermediate upon var. *S. alba* (? *vitellina*) in Switzerland; (2) yellow upon var. *S. alba* in Switzerland; (1) whitish-intermediate upon *S. Smithiana*; (4) yellow and (1) whitish-intermediate upon *S. cinerea;* (4) yellow upon *S. triandra;* (1) yellowish-intermediate upon *S. babylonica;* (12) yellow and (3) yellowish-intermediate upon *S. rubra.* All, except the five in Switzerland, were found at Oxford.

Conclusions from Captured Larvæ; Reconciliation of Conflicting Evidence.—The results recorded above were very uniform. Only in the case of *S. cinerea* was there any great difference between the larvæ on the same tree, for the Swiss varieties of *S. alba*, which produced yellowish larvæ, had leaves resembling *S. rubra* rather than the ordinary English *S. alba*, with one exception (which produced the white larva). At the same time there were two instances which perplexed me for a long time, and finally suggested the explanation which clears up the greatest difficulty in the way of the theory—the conflicting evidence (Mr. Boscher's and my own) with regard to the action of *S. viminalis.* These instances were, the yellowish intermediate larva upon *S. linearis* and the yellow one upon *S. incana.* Both the trees had small narrow leaves with very white under sides, and yet the larvæ were not white. *S. linearis* is whiter than apple or any sallow that I have seen. Then I remembered that the single yellow larva I had found upon *S. viminalis* (in 1884) was upon a tree with very small leaves; finally, I had the opportunity of looking at twigs from the trees upon which Mr. Boscher had found about eighteen yellow larvæ. These, too, bore very small leaves, although they were as white as usual on the under sides. This association of yellow larvæ with small leaves (although white) suggested the following explanation. It is the *immediate* environment almost in contact with the larva which has the greatest effect upon it, and the longer it acts the more extreme will be the result. The larvæ habitually rest upon the under sides of the leaves, until their size and weight render it impossible for them to do so longer; then they retire to the stem. Hence the larvæ rest for a much longer period of their lives upon large and strong leaves than upon small ones, and therefore, in the former case, the effect of the white under sides is much more powerful, for after the larva has reached the stem the immediate environment is less exclusively white, and may be largely formed by the green or yellowish upper sides of the leaves (depending upon the arrangement of the latter). This completely explains the conflicting results upon *S. viminalis*, for there is an immense difference in size between the leaves of the two forms upon which the two varieties of larva have been found; and the arrangement is also different, tending to produce a white environment after the larva has gone to the stem in the case of the large-leaved trees, but not in the small-leaved forms. This explanation is valid for other food-plants in exact proportion to the difference in colour between the two sides of their leaves. Thus it is probable that it explains in a great measure the yellow effect of the small-leaved *S. cinerea*, and the much whiter effect of the large-leaved *S. Smithiana;* both having very similar leaves with white under sides. It also explains the very powerful effect of apple, with its large strong leaves, which are arranged so as to give a maximum white effect after the larva has retired, very late in life, to the stem. Another difficulty is also cleared up by this suggestion—the fact that bred larvæ in 1884 and 1885 became intermediate upon large-leaved *S. viminalis*, although they tended towards white (as shown by the effect of other plants). The long leaves were disarranged when crowded into the glass cylinders in which the larvæ were kept, and so the immediate environment of the larvæ was artificially altered when they were on the under sides of the leaves, and also on the stem. Furthermore, they were often disturbed by changing the food, and so did not rest upon the white surfaces for such long periods as in the natural state. The larvæ found in the field upon *S. rubra* and plants tending towards yellow were much more extreme varieties than those produced by breeding. This is partly due to the hereditary influence towards white in the latter case, but also probably to the white muslin which was tied over the breeding cylinders, and to the less amount of direct sunlight obtainable indoors and among the crowded leaves. In the field the larvæ habitually rest on the most exposed and tallest boughs, of which the colours are most brightened by sunlight, and such an environment therefore produces a very strong influence upon them. Such considerations suggest that it will be very interesting to breed the larvæ under coloured light, and I intend to make the experiment this summer.

Conclusion.—The whole evidence for the theory of colour-relation advanced in the present paper consists of 204 instances, of which about half were bred and the rest found in the field. Such is the evidence for the conclusion that the larva of *Smerinthus ocellatus* maintains a colour-relation with the food-plant upon which it was hatched, adjustable within the limits of a single life, and that the predominant colour of the food-plant itself is the stimulus which calls up a corresponding larval colour. This is an entirely new resource in the various schemes of larval protection by resemblance to the environment, and one which stands on a very different level from all others. In the latter the gradual working of natural selection has finally produced a resemblance, either general or special, to something which is common to all the food-plants of the larva or to some one or more of them, the larva being less protected upon the remainder. But in the former case the same gradual process has finally given the larva a power which is (relatively) immediate in its action, and enables the organism itself to answer with corresponding colours the differences which obtain between its food-plants. This action is very different from the much more rapid changes of colour in other organisms (amphibia, fish, &c.), for in them the changing colours of the environment act as stimuli, which, through a nervous circle, modify the condition of existing pigments; while in the larva the influence makes itself felt in the absorption and production of pigments rather than their modification when formed; and such a method of gaining protection is, as far as we yet know, unique in the animal kingdom. And the power is not confined to the species in which its existence has been to some extent completely proved. There are already proofs that many other larvæ can maintain a similar colour-relation, and careful observation will doubtless reveal many slight and protective differences among larvæ of the same species when found upon differently-coloured food-plants, and will prove that this power is not at all uncommon among the great body of lepidopterous larvæ which adopt the methods of protective resemblance.

February 11.—"On the Theory of Lubrication and its Application to Mr. Beauchamp Tower's Experiments, including an Experimental Determination of the Viscosity of Olive Oil." By Prof. Osborne Reynolds, LL.D., F.R.S.

The application of the hydrodynamical equations for viscous fluids to circumstances similar to those of a journal and a brass in an oil-bath, in so far as they are known, at once led to an equation [1] between the variation of pressure over the surface and the velocity, which appeared to explain the existence of the film of oil at high pressure.

This equation was mentioned in a paper read before Section A at the British Association, at Montreal. It also appeared from a paragraph in the Presidential Address (p. 14, B.A. *Report*, 1884) that Prof. Stokes and Lord Rayleigh had simultaneously arrived at similar results. At that time the author had no idea of attempting the integration of this equation. On subsequent consideration, however, it appeared that the equation might be so transformed [2] as to be approximately integrated by considering certain quantities small, and the theoretical results thus definitely compared with the experimental.

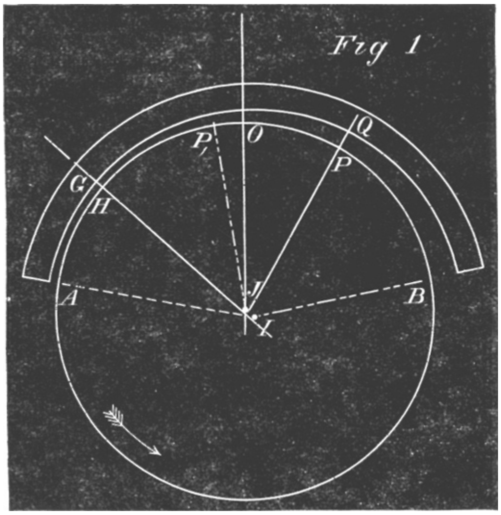
The result of this comparison was to show that with a particular journal and brass the mean thickness of the film would be sensibly constant for all but extreme values of load divided by viscosity, and hence if the coefficient of viscosity were constant the resistance would increase approximately as the speed.

As this was not in accordance with Mr. Tower's experiments, in which the resistance increased at a much slower rate, it appeared that either the boundary actions became sensible, or that there must be a rise in the temperature of the oil which had escaped the thermometer used to measure the temperature of the journal.

That there would be some excess of temperature in the oil film on which all the work of overcoming friction is spent is certain, and after carefully considering the means of escape of this heat, it appeared probable that there would be a difference of several degrees between the oil-bath and the film of oil.

This increase of temperature would be attended with a diminution of viscosity, so that as the resistance and temperature increased with the velocity there would be a diminution of viscosity, which would cause the increase of the resistance with the velocity to be less than the simple ratio.

In order to obtain a quantitative estimate of these secondary effects, it was necessary to know the exact relation between the viscosity of the oil and the temperature. For this purpose an experimental determination was made of the viscosity of olive oil at different temperatures as compared with the known viscosity of water. From the result of these experiments an



No. of equation in the paper

[1] $$\frac{dp}{dx} = \frac{6\mu U\,(h - h_1)}{h^3} \quad . \; . \; . \; . \; . \; (31)$$

in which p is the intensity of pressure, μ coefficient of viscosity, x the direction of motion, h the interval between the journal and the brass, h_1 being the value of h for which the pressure is a maximum, U the surface velocity in the direction of x.

[2] If the journal and brass are both of circular section, as in Fig. 1, and R is the radius of the journal, R + a radius of brass, J the centre of the journal, I the centre of the brass, JI = ca, HG the shortest distance across the film, IO the line of loads through the middle of the brass, A the extremity of the brass on the off side, B on the on side, P_1 the point of greatest pressure

putting
$$\mathrm{OIH} = \phi_0 - \frac{\pi}{2}$$
$$\mathrm{OIP}_1 = \phi_1$$
$$\mathrm{OIP} = \theta$$
$$h = a\left\{1 + c \sin(\theta - \phi_0)\right\}$$
$$h_1 = a\left\{1 + c \sin(\phi_1 - \phi_0)\right\}$$

the equation (31) becomes

$$\frac{dp}{d\theta} = \frac{6\mathrm{R}\mu c\left\{\sin(\theta - \phi_0) - \sin(\phi_1 - \phi_0)\right\}}{a\left\{1 + c\sin(\theta - \phi_0)\right\}^3} \quad . \; . \; (48)$$

if $\frac{a}{\mathrm{R}}$ is small. This equation, which is at once integrable when c is small, has been integrated by approximation when c is as large as 0·5.

The friction is given by an equation

$$f = -\tfrac{1}{2}\mathrm{R}\frac{d\theta}{dp}a\left\{c\sin(\theta - \phi_0)\right\} - \mu\frac{\mathrm{U}_1 - \mathrm{U}_0}{a\left\{1 + c\sin\theta - \phi_0\right\}} \quad . \; . \; (49)$$

This is also approximately integrated up to $c = 0{\cdot}5$.

ϕ_0 and ϕ_1 and c have to be determined from the conditions of equilibrium, which are

$$\int_{-\theta_1}^{\theta_1}\left\{p\sin\theta - f\cos\theta\right\}dp = 0 \quad . \; . \; . \; . \; (44)$$

$$\int_{-\theta_1}^{\theta}\left\{p\cos\theta + f\sin\theta\right\}d\theta = \frac{\mathrm{L}}{\mathrm{R}} \quad . \; . \; . \; . \; (45)$$

$$\int_{-\theta}^{\theta} f d\theta = \frac{\mathrm{M}}{\mathrm{R}^2} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; (46)$$

where $2\theta_1$ is the angle subtended by the brass, L the load, and M the moment of friction.

The solution of these equations may be accomplished when c is small, and has been approximately accomplished for particular values of c up to 0·5, the boundary conditions as regards p being

$$\theta = \pm\,\theta_1 \qquad p = p_0,$$

whence substituting the values of ϕ_1, ϕ_0, c in (48) and (49), and integrating, the values of the friction and values of the pressure are obtained.

empirical formula has been deduced for the viscosity of olive oil at all temperatures between 60° and 120° F.[1]

Besides the effect on μ the temperature might, owing to the different expansion of brass and iron, produce a sensible effect on the small difference a in the radii of the brass and journal, *i.e.* on the mean thickness of the film. E was taken for the coefficient of this effect, and since, owing to the elasticity of the material, the radius would probably alter slightly with the load, m was taken as a coefficient for this effect, whence a is given by an equation[2] in terms of a_0, its value with no load and a temperature zero.

Substituting these values in the equations, the values of the pressure and friction deduced from the equations are functions of the temperature, which may be then assumed, so as to bring the calculated results into accord with the experimental.

There was, however, another method of arriving, if not at the actual temperatures, at a law connecting them with the frictions, loads, and velocities. For the rise in temperature was caused by the work spent in overcoming friction, while the heat thus generated had to be carried or conducted away from the oil film. Consideration of this work and the means of escape gave another equation between the rise of temperature, the friction, and velocity.[3]

The values of the constants in this equation can only be roughly surmised from these experiments, without determining them by substituting the experimental values of f, U, and T, as previously determined, but it was then found that the experiments with the lower loads gave remarkably consistent values for A, B, E, m, and a_0, which was also treated as arbitrary. In proceeding to the higher loads for which the values of c were greater, the agreement between the calculated and experimental results was not so close, and the divergence increased as increased. On careful examination, however, it appeared that this discordance would be removed if the experimental frictions were all reduced 20 per cent. This implied that 20 per cent. of the actual friction arose from sources which did not affect the pressure of the film of oil; such a source would be the friction of the ends of the brass against flanges on the shaft commonly used to keep the brass in its place, or by any irregularity in the longitudinal section of the journal or brass. A coefficient, n, has therefore been introduced into the theory, which includes both the effect of necking and of irregularity in longitudinal section. Giving n the value 1·25, the calculated results came into accordance with all Mr. Tower's results for olive oil, the difference being such as might well be attributed to experimental inaccuracy, and this both as regards the frictions measured with one brass, No. 1, and the distribution of the pressure round the journal with another, No. 2.

Not only does the theory thus afford an explanation of the very novel phenomena of the pressure in the oil film, but it also shows, what does not appear in the experiments, how the various circumstances under which the experiments have been made affect the results.

Two circumstances in particular which are brought out as principal circumstances by the theory seem to have hitherto entirely escaped notice, even that of Mr. Tower.

One of these is a, the difference in the radii of the journal and of the brass or bearing. It is well known that the fitting between the journal and its bearing produces a great effect on the carrying power of the journal, but this fitting is supposed to be rather a matter of smoothness of surface than a degree of difference in radii. The radius of the bearing must always be as much larger than that of the journal as is necessary to secure an easy fit, but more than this does not seem to have been suggested.

It now appears from this theory that if viscosity were constant the friction would be inversely proportional to the difference in the radii of the bearing and journal, and this although the arc of contact is less than the semi-circumference; and taking temperature into account it appears from the comparison of the theoretical frictions with the experiment on brass No. 1 that the difference in the radii at 70° F. was

$$a = 0{\cdot}00077 \text{ (inch)},$$

and comparing the theoretical pressures with those measured with brass No. 2,

$$a = 0{\cdot}00084 \text{ (inch)},$$

or the difference was 9 per cent. greater in the case of brass No. 2.

Another circumstance brought out by this theory, and remarked on both by Lord Rayleigh and the author at Montreal, but not before suspected is, that the point of nearest approach of the journal to the brass is not by any means in the line of load, and, what is still more contrary to common supposition, it is on the *off*[1] side of this line.

This point H moves as the ratio of load to velocity increases; when this ratio is zero, the point H coincides with O, then as the load increases it moves away to the left, till it reaches a maximum distance $\frac{\pi}{2} = \phi_0$, being nearly $-\frac{\pi}{2}$. The load is still small, smaller than anything in Mr. Tower's experiments, even with the highest velocities. For further increase of load, H returns towards O, or $\frac{\pi}{2} - \phi_0$ increases. With the largest loads and smallest velocities to which the theory has been applied this angle is about 40°. With a fairly loaded journal well lubricated it would thus seem that the point of nearest approach of brass to journal, *i.e.* the centre of wear, would be about the middle of the off side of the brass.

This circumstance, the reason of which is rendered perfectly clear by the conditions of equilibrium, at once explains a singular phenomenon, incidentally pointed out by Mr. Tower, viz. that the journal having been run in one direction for some time, and carrying its load without heating, on being reversed began to heat again, and this after many repetitions always heating on reversal, although eventually this tendency nearly disappeared. Mr. Tower's suggested explanation appears to the author as too hypothetical to be satisfactory, even in default of any other; and particularly as this is an effect which would necessarily follow in accordance with the theory, so long as there is wear. For the centre of wear, being on the *off* side of the line of loads, this wear will tend to preserve or diminish the radius of the brass on the *off* side, and enlarge it on the *on* side, a change which will, if anything, improve the condition for producing oil pressure while running in this direction, but which will damage the condition on which the production of pressure in the film depends when the journal is reversed and the late *off* side becomes the new *on* side. That with a well-worn surface there should be sufficient wear to produce this result with such slight amounts of using as those in Mr. Tower's experiments before reversal seems doubtful, but supposing the brass new and the surface more or less unequal, the wear for some time would be considerable, even after the initial tendency to heat had disappeared. Hence it is not surprising that the effect should have eventually seemed to disappear.

The circumstances which determine the greatest load which a bearing will carry with complete lubrication, *i.e.* with the oil film continuous between brass and journal throughout the entire arc, are definitely shown in the theory, so long as the brass has a circular section.

The theory shows that the ultimate limit to the load will be the same with the oil-bath and with partial lubrication as Mr. Tower found it to be.

The effect of the limited length of bearings, and the escape of the oil at the ends, is also apparent in the equations.

Although in the main the present investigation has been directed to the circumstances of Mr. Tower's experiments, namely, a cylindrical journal revolving in a cylindrical brass, the main object has been to establish a general and complete theory based on the hydrodynamical equations for viscous fluids. Hence it has been thought necessary to proceed from the general equations, and to deduce the equations of lubrication in a general form, from which the particular form for application has been obtained. It has been found necessary also to consider somewhat generally the characters of fluid friction and viscosity.

The verification of the equations for viscous fluids under such extreme circumstances affords a severe test of the truth and com-

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[1] An inch being unit of length, a pound unit of force, and a second unit of time, for olive oil

$$\mu = 0{\cdot}00004737e^{-0{\cdot}0221\mathrm{T}} \quad \ldots\ldots \quad (8)$$

[2] $$a = (a_0 + m\mathrm{L})e^{\mathrm{ET}} \quad \ldots\ldots\ldots \quad (117)$$

[3] $$f = \left(\mathrm{A} + \frac{\mathrm{B}}{\mathrm{U}}\right)\mathrm{T} + \mathrm{EAT}^2 . \quad \ldots\ldots \quad (120)$$

A + ET represents the rate at which the mechanical equivalent of heat is carried away per unit of temperature; B represents the rate at which it is conducted away.

[1] *On* and *off* sides are used by Mr. Tower to express respectively the sides of approach and recession, as B and A, Fig. 1, the arrow indicating the direction of motion.

pleteness of the assumptions on which these equations are founded; and the result of the whole research is to point to a conclusion (important to natural philosophy) that not only in cases of intentional lubrication, but wherever hard surfaces under pressure slide over each other without abrasion, they are separated by a film of some foreign matter, whether perceptible or not; and that the question as to whether the action can be continuous or not turns on whether the motion tends to preserve the foreign matter between the surfaces at the points of pressure, as in the almost if not quite unique case of the revolving journal, or tends to remove it, and sweep it on one side, as in the action of all backward and forward rubbing with continuous pressure.

The fact that a little grease will enable any surfaces to slide for a time has tended doubtless to obscure the action of the revolving journal to maintain the oil between the surfaces at the point of pressure, and yet, although only now understood, it is this action that has alone rendered machinery or even carriages possible. The only other self-acting system of lubrication is that of reciprocating motion with intermittent pressure and intermittent separation of the surfaces to draw the oil back or to draw a fresh supply. This is important in certain machinery, as in the steam-engine, and is as fundamental to animal mechanism as is the continuous lubricating action of the journal to mechanical contrivances.

Mathematical Society, March 11.—Mr. J. W. L. Glaisher, F.R.S., President, in the chair.—Mr. L. J. Rogers was admitted into the Society.—Prof. Sylvester, F.R.S., read a paper on an instantaneous proof of the expression for the number of linearly independent invariants or seminvariants of a given type, and also of the corresponding expression for reciprocants.—Mr. E. B. Elliott read a paper on ternary and *n*-ary reciprocants, and Mr. L. J. Rogers read one entitled "Homographic, Circular, and Projective Reciprocants."—Capt. P. A. Macmahon, R.A., communicated a proof of Cayley's fundamental theorem of invariants, and Mr. Leudesdorf communicated a note by Mr. Griffiths, on the invariantisers of a binary quantic.—Mr. Tucker (Hon. Sec.) called the attention of the Society to a paper read before the Royal Irish Academy (January 26) by Dr. Casey, F.R.S., entitled "On the Harmonic Hexagon of a Triangle," in which properties established by himself for a harmonic quadrilateral were beautifully generalised and extended to the harmonic hexagon and other harmonic polygons. The harmonic hexagon is thus defined:—$A B C$ is any triangle, $A A'$, $B B'$, $C C'$ its symmedian lines, which meet the circumcircle in $A' B' C'$; the figure $A B' C A' B C'$ is the harmonic hexagon. Dr. Casey calls the triangles $A' B' C'$, $A B C$ cosymmedian triangles.—Mr. Tucker then communicated, for the Rev. T. C. Simmons, the following extensions:—Let K' be the inverse point of the symmedian point K with respect to the circumcircle, and let $K' A$, $K' B$, $K' C$ meet this circle in $A'' B'' C''$; then $A'' B'' C''$ may be called the inverse cosymmedian triangle of $A B C$. What Dr. Casey has proved for cosymmedian triangles, Mr. Simmons shows also for these inverse triangles, and the result is that the three sets of triangles have the same Brocard points, symmedian point, Brocard, "T. R.," sine and cosine circles.—Mr. Simmons also sent a construction for finding a triangle whose Brocard points and angle are given, whence he proves that *any* triangle inscribed in a certain circle and circumscribed to the Brocard ellipse has the given Brocard points for B. points.

Linnean Society, March 4.—Sir John Lubbock, Bart., F.R.S., President, in the chair.—Messrs. Gilbert C. Bourne, William H. Catlett, and Thos. A. Cotton were elected Fellows of the Society.—One of nine volumes of water-colour drawings of British plants, by the late Miss Moseley of Great Malvern, was exhibited for Miss Onslow.—A paper on *Strongylus Arnfieldi* and *S. tetracanthus*, by Prof. Spencer T. Cobbold, was read, and specimens illustrating the encysted stage of the latter exhibited. Of Arnfield's strongyle he drew attention to the morphology of the hood and its rays, the position of the vulva, and the structure of the embryo, contrasting these with those of allied forms. Regarding his observations on the four spined strongyle these may be summarised as follows:—(1) The eggs are expelled from the parent in a state of fine yolk-cleavage; (2) embryos are formed after egg expulsion, and a few days subsequently escape from the envelopes, undergoing a primary change of skin in moist earth during warm weather; (3) thereafter they live many weeks as rhabdiform nematoids; (4) in all likelihood an intermediary host is unnecessary; (5) the rhabdiform larvæ are passively transferred to their equine bearers either with fresh-cut fodder, or while the animals are grazing; (6) transferred to the intestinal canal they enter the walls of the cæcum and colon, encyst themselves, and undergo change of skin; (7) their presence in the intestinal walls is associated with certain pathological conditions, frequently fatal to the bearer; (8) ordinarily the young worms perforate their cysts and migrate to the lumen of the bowel, and indications of sex appear at this the "Trichonema stage"; (9) they next form cocoons by agglutination of vegetable debris within the gut, and undergo a third skin-casting, with intestinal metamorphosis; (10) lastly, their internal sexual organs and the completion of definite form are acquired within the colon of the host.—A paper was read by Mr. G. Murray on a new species of *Rhipilia* from the Mergui Archipelago. This was collected by Dr. J. Anderson (of Calcutta Museum) in 1882, and recently presented to the British Museum. It was found growing on mud flats at King's Island Bay. The genus *Rhipilia* was established by Kützing for the reception of two species—*R. tomentosa* and *R. longicaulis*—collected by Sonder in the Antilles. To these Prof. Dickie added *R. Ransoni* from Barbadoes. The new species, *R. Andersoni*, differs from the two former in the frond being completely sessile on the mass of rhizoids, and from the latter in the sessile frond being entire. A hitherto unidentified, imperfect specimen brought by Cumming from the East (Philippines?) is now found to be identical with Dr. Anderson's example, which is well preserved in spirit, and thus the Oriental habitat of the genus is corroborated. The author describes minutely and illustrates the remarkable rhizoid filaments of *R. Andersoni*.—A second paper was read by Mr. G. Murray, viz. on two new species of *Lentinus*, one of them growing on a large *Sclerotium*.—Mr. J. G. Baker afterwards gave orally the gist of a communication on a collection of ferns made in North Borneo by the Bishop of Singapore and Sarawak.

Physical Society, February 27.—Dr. J. H. Gladstone in the chair.—Dr. Sydney Young and Mr. D. E. Jones were elected members of the Society.—The following communications were read:—The relations of pressure, temperature, and volume in saturated vapours, by Prof. W. C. Unwin. In the first part of this paper certain formulæ given by Messrs. Ramsay and Young in a recent communication on some thermodynamical relations are criticised. The most important of these is the statement that for different saturated vapours at the same pressure $p\frac{dp}{dt}$ is constant. Prof. Unwin finds, however, that $t\frac{dp}{dt}$ is less constant than $t^2\frac{dp}{dt}$, while $\frac{t^2}{p}\frac{dp}{dt}$ is nearly a constant quantity for all saturated vapours under any conditions. This result suggested that

$$\frac{t^{n+1}}{p}\frac{dp}{dt}$$

might be more nearly constant, and the integration of this gives

$$\log p = a - \frac{b}{t^n},$$

a formula to the examination of which the second part of the paper is devoted. From it may be derived the following relations in which for convenience in calculation the logarithms given are to the base 10.

$$t = \left(\frac{b}{a - \log p}\right)^{\frac{1}{n}}$$

$$\frac{1}{p} \cdot \frac{dp}{dt} = 2{\cdot}3025\,\frac{nb}{t^{n+1}}$$

$$= 2{\cdot}3025\,n\,\frac{(a - \log p)^{\frac{n+1}{n}}}{b^{\frac{1}{n}}}$$

$$\frac{t}{p} \cdot \frac{dp}{dt} = 2{\cdot}3025\,\frac{nb}{t},$$

&c. These formulæ have been examined in the case of steam from − 30° to 230° C., and with pressures varying from ·4 to 20,000 mm. The constants were found to be

$$a = 7{\cdot}5030 \quad \ldots \quad b = 7579 \quad \ldots \quad n = 1{\cdot}25,$$

and the differences between the calculated results and the observations of Regnault and Zeuner rarely exceeded 1 per cent., while generally much smaller. a, b, and n have also been found for some other substances, with the following results:—

Alcohol ... ... $a = 7{\cdot}448$ ... $b = 8784$ ... $n = 1{\cdot}29$
Ether ... ... $a = 6{\cdot}9968$ ... $b = 3047$ ... $n = 1{\cdot}153$
Mercury ... $a = 9{\cdot}8651$ ... $b = 597{\cdot}5$ ... $n = {\cdot}69$
Carbonic acid $a = 8{\cdot}4625$ ... $b = 302{\cdot}8$ ... $n = {\cdot}77$

Prof. Perry offered some criticisms upon this paper, and believed that for practical purposes the expressions given would not be found superior to Rankine's formula

$$\log p = a - \frac{b}{t} - \frac{c}{t^2},$$

which gives p in terms of t, and and a quadratic expression for obtaining t in terms of p. He also observed that the chief aim of Ramsay and Young's paper was to obtain relations between the pressure and temperature of different saturated papers, so that the connection between temperature and pressure having been observed and recorded for one vapour, that for any other vapour could be at once deduced from it.—On a map of the world in which the proportion of areas is preserved, by Mr. Walter Baily. The author had devised a method for constructing such a map, but has subsequently found that one precisely similar was employed by Flamsteed in 1729 for charting the stars in his "Atlas Cœlestis." The construction applied to the earth is briefly as follows. Draw a straight line to represent the meridian that is to occupy the centre of the map. Divide this line into equal parts representing upon a convenient scale the distance between the parallels of latitude, and through these points draw a series of lines at right angles to the original line; these are the parallels of latitude. Mark off on these the actual distances at which the meridians cut them; through the points so found the meridians may be filled in, and the map constructed. From the method of construction it is evident that, although the outlines in the map are distorted, the amount of distortion increasing with the distance from the central meridian, the proportionality of areas is preserved, a fact which the author believes will render the map useful for recording rainfall, depth of sea, ocean currents, &c.—On a delicate calorimetric thermometer, by Prof. S. U. Pickering.

Edinburgh

Royal Society, February 1.—Mr. J. Murray, Vice-President, in the chair.—Several obituary notices were read.—Dr. Thomas Muir read the second part of a paper on the theory of determinants in the historical order of its development.—Mr. G. Brook communicated a paper on the origin and formation of the germinal layers in the Teleostei.—Mr. A. C. Mitchell described the results of experiments on the thermal conductivity of ice. A method involving periodic variation of temperature was used.

February 15.—Mr. R. Gray, Vice-President, in the chair.—Mr. W. Durham read a paper on chemical affinity and solution.—Mr. J. T. Cunningham, of the Scottish Marine Station, read a paper on the reproductive elements of *Myxine glutinosa.*—Dr. J. R. Buist communicated a paper on the life-history of the micro-organisms associated with Variola and Vaccinia.—Mr. A. P. Laurie discussed the probable heats of formation of zinc-copper alloys, as determined by observations on the E.M.F. of constant voltaic cells with the alloys as negative elements. His results indicate the formation of a compound of the formula $CuZn_2$ with an evolution of heat producing a fall of E.M.F. equal to 0·5 volt.—Prof. Tait, in a paper on the mean free paths in a mixture of two systems of spheres, generalised his results as given in previous papers.—Prof. Duns read a paper on two shrunk human heads from South America.

March 1.—Prof. Douglas Maclagan in the chair.—Sir W. Thomson read a paper on the magnitude of the mutual attraction between two pieces of matter at distances of less than 10 micro-millimetres.—Prof. Tait read a paper on a theorem in the science of situation.—Mr. John Aitken communicated a paper on radiation from snow, and also a paper on thermometer screens.—Mr. J. H. Pollok discussed the relation between the volume of an aqueous solution of a salt and the sum of the columns of its constituents.—Mr. W. Peddie read a paper on the increase of electrolytic polarisation with time.

Mathematical Society, March 12.—Mr. W. J. Macdonald in the chair.—Mr. Harry Rainy read a paper on bifilar suspension treated by the method of contour lines, and Mr. J. S. Mackay gave an abstract, with notes, of a paper of Euler's, entitled "Solutio facilis problematum quorumdam geometricorum difficillimorum."—A conversation took place regarding work to be done under the auspices of the Society by groups of members, with the result that investigations were undertaken on linkages, projective geometry, and the bibliography of mathematical periodicals.

Paris

Academy of Sciences, March 8.—M. Jurien de la Gravière, President, in the chair.—Foundation of a hospital for the treatment of rabies. The following articles have been adopted by the Commission appointed by the Academy to promote this object:—(1) An establishment for the treatment of rabies after the bite of a mad animal shall be founded in Paris under the title of "Institut Pasteur"; (2) this Institute shall admit Frenchmen and foreigners bitten by dogs or other mad animals; (3) a public subscription shall be opened in France and abroad for the foundation of this establishment; (4) the funds thus raised shall be applied under the direction of a Committee appointed for the purpose; (5) subscriptions received by the Bank of France and its branches, the Crédit Foncier and its branches, the Treasury, and public receivers. Names of all subscribers to be inserted in the *Journal Officiel*. Amongst the Committee are the names of MM. Jurien de la Gravière, Pasteur, Bertrand, Vulpian, Marey, Paul Bert, de Freycinet, Magnin (Governor of the Bank of France), Baron Alphonse de Rothschild, and the Perpetual Secretaries of the Academies of Sciences, Inscriptions et Belles Lettres, Beaux Arts, and Moral and Political Sciences.—Determination of the elements of refraction: the most convenient practical solution of the problem, by M. Lœwy. Compared with the older methods here passed in review, the new process enables the observer to obtain in a single month a greater precision than was formerly possible after fifteen years of observations and researches of all sorts required to determine the instrumental constants.—Remarks on the danger of fire arising from the use of nitric acid in the manufacture of certain industrial objects, and especially of explosive substances, such as gun-cotton and dynamite, by M. G. Lechartier. Several instances are mentioned of straw and other organic substances when heated, and even at a low temperature, taking fire by accidental contact with this acid.—Equatorial observations of Brooks's, Barnard's, and Fabry's comets, made at the Observatory of Bordeaux in February 1886, by MM. G. Rayet and Courty.—Observation of the nebula in Maia, by M. Perrotin. In a letter addressed from Nice to M. Mouchez the writer states that by masking Maia he was able distinctly to observe the nebula discovered by MM. Henry, first on February 28, and again, in company with MM. Thollon and Charlois, on March 3 and 4.—On the construction of objectives for instruments of precision, by M. Léon Laurent. The objectives here described and illustrated have been executed by practical methods, which, according to the author, yield the best possible results. They have a diameter of 70 mm. with focus 735 mm.—On the isomeric states of the sesquichloride of chromium: gray hydrated chloride; anhydrous chloride, by M. A. Recoura. The author's researches have led to the determination of two isomeric varieties—a gray chloride and a green chloride, with which latter is connected the violet anhydrous chloride. Dissolved in water, both varieties constitute two extreme states capable of being transformed one into the other by passing through all the intermediate states, the gray-blue solution constituting the stable state of the extended solutions, the green solution the stable state of the highly-concentrated solutions. In another paper it will be shown that these are not the only varieties of chloride.—Note on a combination of methylic alcohol and sulphate of copper, by M. de Forcrand.—On the action of ammonia and water on chloroform, by M. G. André. Some details are given regarding the use of ammonia in aqueous solutions, with indications of the relative proportions of the products resulting from this reaction.—Note on the action of picric acid on terebenthene and on thymene, by M. Lextreit.—On the histogenesis of the elements contained in the ovaries of insects, by M. J. Perez.—On the anatomy of the reproductive organs of Pontobdella (*P. muricata*, Leach), by M. G. Dutilleul.—A contribution to the study of the Miocene palms of Brittany, by M. Louis Crié.—On the distribution of inverted formations in the region of the Jura comprised between Geneva and Poligny, by M. Bourgeat.—Note on a method of direct analysis of rocks by means of their physical properties, by M. Thoulet. The physical properties of which the author avails himself in this process are weight, specific heat, density, and the coefficient of cubic expansion (variation of density with temperature), the two last being easily determined even with small samples by means of the fluid of iodides already recommended by him.—Remarks on M. Mushketoff's orographic and geological description of Turkestan, by M. Daubrée. Of the three volumes of explanatory text to the map of Russian Turkestan (scale 1 : 1,250,000), the first has now appeared. It contains a summary of the explorations of Turkestan from the remotest times down to the year 1884, and a geological description of the Aralo-Caspian steppes, with a small geological map of Turkestan.

BERLIN

Physical Society, January 22.—Dr. König spoke of some photometers he had quite recently tested in respect of their precision. The simple Bunsen photometer, consisting of a screen of fine writing-paper smeared with a grease spot, laboured under the drawback that it was not possible to contemplate simultaneously the two sides it was desired to compare. There were several modifications of this apparatus planned with a view to overcoming this defect. First, there was the application of two mirrors inclined at 45°, by means of which both surfaces were seen in juxtaposition. Other contrivances for the same purpose were the application of a prism, the edge of which lay in the plane of the screen, the use of two prisms, and, further, the use of two totally reflecting prisms with lenses. The last-named description of photometer, as also the mirror-photometer, were very exact, but it now appeared that it was not possible to cause the spot of grease wholly to vanish from view. For such precise photometers there would, on the contrary, have to be found two substances which reflected and transmitted the light differently, but yet absorbed it with equal strength and possessed the same structure. Weber's photometer was constructed according to an entirely different principle. It consisted in the main of a small benzene lamp, which was placed in a tube in front of a mirror and which illumined a milk-glass plate displaceable in the tube. From the illumined milk-glass the light was carried to a totally reflecting prism, and thence into the eye-piece, where it lighted up the half of the field of vision. The other half received light from a milk-glass plate standing in the direction of the eye-piece behind the prism. This milk-glass plate was illumined by the light which was to be measured. In the case of like-coloured light the registrations of the Weber photometer were very exact, but in the case of different-coloured lights such precision was not obtained. Of the means employed by Herr Weber to measure different-coloured lights with his photometer, that which consisted in bringing first a red, then a green, and thereafter a blue glass before the eye-piece, and taking the average of the three measurements, was still at this day the most approximately exact, but was yet inadequate. A great advantage belonging to the Weber photometer, on the other hand, was that by means of it the scattered daylight could be measured. The readily available Weber photometer would prove itself particularly useful for the purpose of testing the conditions of illumination in school-rooms.—Dr. Grunmach reported on the barometric investigations carried out by him in the Normal Gauging Office. He described at length the arrangement of the normal barometer, the vacuum of which was measured in an electrical way. A combination of the barometer-vacuum with a Geissler tube permitted the attenuation to be examined even beyond the limits of the pressures measurable by the cathetometer. The occurrence of the phosphorescence light in the spectral tube was a standard for the highest degrees of attenuation, in which the vacuum was filled with quicksilver vapour of the tension of only 0·01 to 0·02. A still better vacuum would be achieved when the quicksilver vapour was made to be absorbed, a condition which the speaker had in vain tried to effect with selenium. With this barometer was compared a large number of normal barometers according to a method described at large by the speaker, and with the application of the developed formulæ of reduction. Under these comparisons it appeared that the impurity of the free quicksilver-cup heightened the meniscus, and thereby the registrations also of the barometer. In the case of older barometers, a series of other disturbing influences likewise showed themselves, which would have to be further investigated. In the discussion which followed this address, Dr. Goldstein proposed for the electrical measurement of the vacuum, instead of Geissler's spectral tube, the employment of a wide tube which let the fluorescence light pass more obviously into the phenomenon; and for the graduations of these highest degrees of attenuation the thermometer would, he maintained be better adapted than were the optical phenomena. Let, namely, a thermometer be brought into a vacuum-tube whose positive pole was a point, but whose negative electrode was a steel plate nearly filling out the tube in front of the cathode; then the thermometer, when the attenuation reached such a degree that the cathode light appeared would mount 80° to 90° above the temperature of the room. At the positive pole the thermometer rose only about 3°. This rise of temperature in the cathode light occurred in connection with the degree of attenuation, and might be utilised for the measurement of these degrees.

BOOKS AND PAMPHLETS RECEIVED

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CONTENTS

PAGE
A Text-Book of Political Economy. By Prof. R. Adamson . . . 457
Algæ . . . 458
Our Book Shelf:—
Ripper's "Practical Chemistry, with Notes and Questions on Theoretical Chemistry" . . . 459
Greenwood's "Free Public Libraries."—**W. Odell** 459
Grilleau's "Aérostats dirigeables" . . . 460
Letters to the Editor:—
Clifford's "Mathematical Fragments."—**R. Tucker** 460
The Upper Wind Currents in the South Indian Ocean and over the N.W. Monsoon.—**Hon. Ralph Abercromby** . . . 460
Glacier Bay in Alaska.—**G. W. Lamplugh** . . . 461
A Correction, and the Distribution of Appendicularia.—**Prof. W. A. Herdman** . . . 461
Morley's "Organic Chemistry"—Correction.—**Dr. F. R. Japp, F.R.S.** . . . 461
"Peculiar Ice-Forms."—**B. Woodd Smith** . . . 461
Remarkable Discovery of Rare Metals in Diluvial Clays . . . 461
Harvard College Museum Report . . . 462
Technical Education in New South Wales . . . 462
Seebohm's History of British Birds . . . 463
Notes . . . 464
Our Astronomical Column:—
Dark Transits of Jupiter's Fourth Satellite . . . 466
Nova Andromedæ of 1885, and Nova Scorpii of 1860 466
Fabry's Comet . . . 466
Barnard's Comet . . . 466
Astronomical Phenomena for the Week 1886 March 21-27 . . . 466
Biological Notes:—
The Pelagic Stages of Young Fishes . . . 467
Danais archippus—an Enterprising Butterfly . . . 467
Geographical Notes . . . 467
The Sun and Stars, III. By J. Norman Lockyer, F.R.S. (*Illustrated*) . . . 469
University and Educational Intelligence . . . 472
Scientific Serials . . . 472
Societies and Academies . . . 473
Books and Pamphlets Received . . . 480